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Computational methods

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Аннотация: *In this article we study the most important problems of computational mathematics - the establishment of calculation rules with the help of which the initial data, using previously created auxiliary circuits and devices, are converted into output data. A computational method is called stable if for any $\varepsilon > 0$ there is a $\delta > 0$ such that the maxsimum output error is less than ε and the maximum input error is less than δ.*

Keywords: *Iteration , working line , matrix element , triangular matrix, solution vector, column, diagonal, algorithm, cycle.*

Consider an inhomogeneous system of linear equations

$$\begin{cases} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n = b_1 \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n = b_2 \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. \\ a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n = b_n \end{cases}$$

that is, Ax = b, which in the sentence that $detA \neq 0$, has a unique solution for any right-hand side of the equations

$x = \{x_1, x_2, \dots, x_n\}$. To find this vector solution, there are two types of methods: calculation based on the elimination method and calculation based on the methods of successive approximations (iterations).

1) ***Simple Gaussian method.*** The well-known elimination method, once converted into an algorithm, consists of two cyclic procedures.

Converting matrix A into a triangular matrix.

1. Let k = l.
2. You should check whether a_{kk} is non-zero.

3. If yes, then the kth line becomes the working line. If not, then we change the k-th line to the l-th (l >k), in which $a_{ik} \neq 0$.
4. For $i = k+1, k+2, \dots, n$ we calculate new matrix elements, which we denote, like the previous ones, according to the rule:

$$a'_{ij} = 0 \qquad \text{для} \quad j = k$$

$$a'_{ij} = a_{ij} + q_i a_{kj} \quad \text{для} \;\; j \neq k,$$

Where $$q_i = -\frac{a_{ik}}{a_{kk}};$$

Let us similarly present the new right-hand sides of the equations:

$$b'_i = b_i + q_i b_k.$$

Increase k by one if $k \leq n-2$. We obtain the upper triangular matrix

$$A' = \begin{bmatrix} a'_{11} & a'_{12} \dots & a'_{1n} \\ 0 & a'_{22} \dots & a'_{2n} \\ \dots & \dots & \dots . \\ 0 & 0 \dots . & a'_{nn} \end{bmatrix}$$

Calculation vector – solutions $x = (x_1, x_2, \dots, x_n)^T$:

1. $x_n = \frac{b'_n}{a'_{nn}}$
2. Для $\quad i = n-1, n-2, \dots, 1$

$$x_i = \frac{1}{a'_{ii}} \left(b'_i - \sum_{j=1}^{n-i} a'_{i,i+j}\, x_{i+j}\right).$$

2) ***Gauss–Jordan method.*** Let's modify the simple Gauss method, namely, let the row number i run through the values from 1 to k – 1 and from k + 1 to n. This will lead to the fact that all elements of the kth column, with the exception of the diagonal element, become equal to 0, and instead of the upper triangular matrix, we now end up with a diagonal matrix

$$A' = \begin{bmatrix} a'_{11} & & 0 \\ & \ddots & \\ 0 & & a'_{nn} \end{bmatrix}$$

Thus, the calculation of the vector solution is significantly simplified:

$$x = \left(\frac{b'_1}{a'_{11}}, \dots, \frac{b'_n}{a'_{nn}}\right)^T$$

However, the number of operations in this method is greater than in the simple Gaussian method.

Decisive for the accuracy of the calculation is the division by a_{kk}, which is necessary when calculating q_i. Therefore, the condition of the Gaussian method for choosing a diagonal element is too weak in terms of accuracy, and the following scheme is often used.

By rearranging rows and columns (the latter must be “labeled” and restored when constructing a vector solution), it is ensured that the element , which has the largest absolute value among all elements that were not previously used as diagonal elements, turns out to be diagonal.

Example. The process of full diagonalization by the Gauss–Jordan method.

Columns s_i and S_i are given for control:

$$s_i = -\sum_{k=1}^{n} a'_{ik} - b'_i$$

$$S_i = \sum_{k=1}^{n} a'_{ik} + b'_i + s_i \equiv 0$$

i	A			b_i	s_i	q_i	S_i
1	-1	3/2	1	9/2	-6	½	
2	2	1	0	-1	-2	Diagonal	
3	$\overline{-1}$	-1	7/4	7/2	-13/4	½	
1	0	2	1	4	-7	Diagonal	0
2	2	$\overline{1}$	0	-1	-2	-1/2	0
3	$\overline{0}$	-1/2	7/4	3	-17/4	¼	0
1	0	2	1	4	-7	-1/2	0
2	2	$\overline{0}$	-1/2	-3	3/2	¼	0
3	$\overline{0}$	0	2	4	-6	Diagonal	0
1	0	2	0	2	-4		0
2	2	$\overline{0}$	0	-2	0		0
3	$\overline{0}$	0	2	4	-6		0
$x^T = (-1, +1, 2)$							

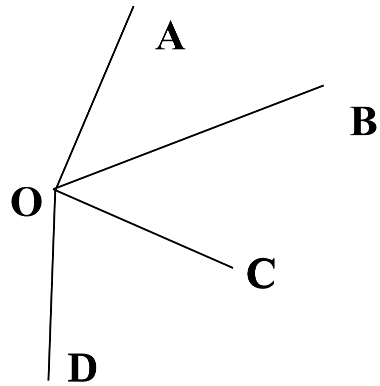
Students can use Gauss, Kruger, Cramer and matrix methods.

The alignment of a triangulation grid measured with equal accuracy using the correlation method.

Measured quantities

№	angles	Measured values , x_i	definition
1	AOB	58^0 15 41,8"	x_1
2	BOC	38 10 06,8	x_2

3	COD	61 01 07,0	x_3
4	AOC	96 25 45,1	x_4
5	BOD	99 11 13,3	x_5
6	AOD	157 26 52,6	x_6



1-picture

Number of conditional equations

$$r = n - k = 6 - 3 = 3$$

we build systems of conditional equations:

$$x_1 + x_2 - x_4 = 0$$

$$x_2 + x_3 - x_5 = 0$$

$$x_1 + x_2 + x_3 - x_6 = 0$$

SYSTEM OF CONDITIONAL AMENDMENT EQUATIONS:

$$V_1 + V_2 - V_4 + W_1 = 0$$

$$V_2 + V_3 - V_5 + W_2 = 0$$

$$V_1 + V_2 + V_3 - V_6 + W_3 = 0$$

OPTIONAL EXPRESSIONS

$W_1 = x_1 + x_2 - x_4 = 58^0\ 15\ 41{,}8'' + 38^0 10'\ 06'',8 - 96^0\ 25'\ 45'',1 = +3,''5$

$W_2 = x_2 + x_3 - x_5 = 38^0\ 10'\ 06'',8 + 61^0\ 01'\ 07'',0 - 99^0\ 11'\ 43'',3 = +0'',\ 5$

$W_3 = x_1 + x_2 + x_3 - x_6 = 58^0\ 15'\ 41'',8 + 38^0\ 10'\ 06'',8 + 61^0\ 01'\ 07'',0 - 157^0\ 26'\ 52'',6 = +\ 3'',0$

LET'S CONSTRUCT CONDITIONAL AMENDMENT EQUATIONS TAKEN INTO CONNECTIONS:

$$V_1 + V_2 - V_4 + 3'',\ 5 = 0$$

$$V_2 + V_3 - V_5 + 0'',\ 5 = 0$$

$$V_1 + V_2 + V_3 - V_6 + 3'',0 = 0$$

COMPLETE A CORRELATION NORMAL EQUATION

$$[a_1\ a_1]\ K_1 + [a_1\ a_2]\ K_2 + [a_1 a_3]\ K_3 + W_1 = 0$$

$$[a_2\ a_1]\ K_1 + [a_2\ a_2]\ K_2 + [a_2 a_3]\ K_3 + W_2 = 0$$

$$[a_3\ a_1]\ K_1 + [a_3\ a_2]\ K_2 + [a_3\ a_3]\ K_3 + W_3 = 0$$

WE TAKE THE DERIVATIVE OF THE CORRECTION EQUATIONS, DETERMINE THE COEFFICIENTS AND ENTER THEM INTO THE TABLE:

	κ_1	κ_2	κ_3			
	a_1]	**a_2]**	**a_3]**	**S]**	**V(")**	**V^2**
1	+1		+1	2	- 0,83	0,69
2	+1	+1	+1	3	- 1	1
3		+1	+1	2	0,68	0.46
4	-1			-1	1,68	2.82
5		-1		-1	0,18	0.03
6			-1	-1	- 0,85	0.72
Σ	+1	+1	+2	+4		

WE CALCULATE THE COEFFICIENTS OF NORMAL EQUATIONS:

	a_1]	**a_2]**	**a_3]**	**S]**	**W_i**
[a_1	+3	+1	+2	+6	+3,5
[a_1	+1	+3	+2	+6	+0,5
[a_1	+2	+2	+4	+8	+0,3
[S	+6	+6	+8	+20	

CONSTRUCTING NORMAL EQUATIONS:

$$3\ \kappa_1 + \kappa_2 + 2\ \kappa_3 + 3{,}5 = 0$$

$$\kappa_1 + 3\ \kappa_2 + 2\ \kappa_3 + 0{,}5 = 0$$

$$2\kappa_1 + 2\ \kappa_3 + 4\ \kappa_3 + 0{,}3 = 0$$

$\kappa_1 = -\ 1{,}675$ $\kappa_2 = -\ 0{,}175$ $\kappa_3 = 0{,}85$

EXAMINATION

$3\ (-\ 1{,}675) - 0{,}175 + 2\ (0{,}85) + 3{,}5 = 0$ $-5{,}\ 025\ \ 0{,}175 + 1{,}7 + 3{,}5 = 0$ $0 = 0$

$-\ 1{,}675 + 3\ (-0{,}175) + 2\ (0{,}85) + 0{,}5 = 0$ $-1{,}675 - 0{,}525 + 1{,}7 + 0{,}5 = 0$ $0 = 0$

$2\ (-1{,}675) + 2\ (-0{,}175) + 4 \cdot (0{,}85) + 0{,}3 = 0$ $-3{,}35 - 0{,}35 + 3{,}4 + 0{,}3 = 0$ $0 = 0$

$V_1 = 1 \cdot (-1{,}675) + 0 + 1 \cdot 0{,}85 = -0{,}825 = -0'',825 = -0.83 = -0.8$

$V_2 = 1 \cdot (-1{,}675) + 1 \cdot (-0{,}175) + 1 \cdot 0{,}85 = -1'',00 = -1{,}00$

$V_3 = 0 + 1 \cdot (-0{,}175) + 1 \cdot 0{,}85 = 0{,}675 = 0{,}675 = 0{,}68 = 0.7$

$V_4 = -1 \cdot (-1{,}675) + 0 + 0 = 1{,}675 = 1''68 = 1{,}7$

$V_5 = 0 - 1 \cdot (-0{,}175) + 0 = 0{,}175 = 0{,}18 = 0{,}2$

$V_6 = 0 + 0 - 1\,(0{,}85) = -0{,}85 = -0'',85 = -0.8$

ENTER THE RESULTS OBTAINED INTO THE TABLE AND DETERMINE THE PROVIDED VALUES:

№	**x_i**	**v_i**	**x_i**	Equations	**x_i**
1	58 15 41,8	- 0,8	58 15 41,0	x_1	58 15 41,0
2	38 10 06,8	- 1,0	38 10 05,8	x_2	38 10 05,8
3	61 01 07,0	+ 0,7	61 01 07,7	x_3	61 01 07,7
4	96 25 45,1	+ 1,7	96 25 46,8	$x_1 + x_2$	96 25 46,8
5	99 11 13,3	+ 0, 2	99 11 13,5	$x_2 + x_3$	99 11 13,5
6	157 26 52,6	- 0,8	157 26 51,8	$x_1 + x_2 + x_3$	157 26 51,8

$$m = \sqrt{\frac{[v^2]}{n-k}} = \sqrt{\frac{5.70}{6-3}} = 1{,}26\,;$$

$$m_m = \frac{m}{\sqrt{2(n-k)}} = \frac{1{,}26}{\sqrt{2(6-3)}} = 0{,}51''$$

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